海洋生物追跡用GPS搭載アルゴス送信機の開発

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はしがき

近年のマイクロエレクトロニクスの急速な発展によって、海洋生物の行動生態研究に画期的な研究手法を適用するに至っている。特に、海洋を地球規模で大回遊するウミガメ類、クジラ類あるいはアホウドリなどの海鳥の追跡では、人工衛星を利用したアルゴルシステムが広範に利用されている。アルゴスシステムによる測位原理は、極軌道衛星にアップリンクした電話のドップラーシフトによるものであることから、原理的な測位精度の誤差が生じ、最善の測位でも１５０ｍ程度の測位誤差がある。

本研究では、原理的に不可避なアルゴスシステムによる測位誤差を回避するために、Global Positining System(GPS)を組み合わせたGPS搭載アルゴス送信機を開発することを目的とした。

本研究期間内に、GPS 搭載アルゴス送信機のプロトタイプを３種類製作した。これらの試作機をタイ国水産局（現　海洋沿岸資源局）傘下のウミガメ保護ステーションの飼育池（約５ヘクタール）において、タイマイの甲羅に装着して実験を繰り返した。一連の実験の結果を踏まえて実海域実験をタイ国のアンダマン海側のパンガ県において、アオウミガメの雌成体を用いて実験を行った。この結果、GPS で得られた測位データはアルゴスシステムで正常に受信することができた。また、その位置情報は同時に得られたアルゴスシステムによる測位情報より格段に正確であることが示された。

本報告書には 2 カ年の研究によって得られた成果を下に執筆された研究発表並びに技術資料を掲載した。

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研究発表

(1) 学会誌等

Nobuaki Arai and Kazuhiko Ono: Development of a GPS-Argos PTT for marine animal tracking, *ARGOS forum*, 59, 19, 2002.

Nobuaki Arai: The results of SEASTAR2000 and related projects in ASEAN countries, Proceedings of International Conference on Informatics Research for Development of Knowledge Society Infrastructure 2004, 122-129, 2004.

(2) 口頭発表

Nobuaki Arai, Kazuhiko Ono and Koichi Mizuno: Development of a GPS-Argos PTT for marine animal tracking, Argos animal tracking symposium, March 24-26, 2003, Annapolis, USA.

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The results of SEASTAR2000 and related projects in ASEAN countries

(Proceedings of International Conference on Informatics Research for Development of Knowledge Society Infrastructure 2004)

by

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The Results of SEASTAR2000 and Related Projects in ASEAN Countries

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Abstract

The Southeast Asia sea turtle associative research (SEASTAR2000) was started in 1999 by the request of the Thai government. The research focused on tracking sea turtles using the Argos system. The results of the research clarified migratory paths of adult female green turtles after their nesting. In order to measure fine scale turtle behaviors, the project included development of new devices including a magnetic field sensor accelerometer tag (MR tag), a GPS-Argos platform terminal transmitter (GPS-Argos PTT) and a visual data storage tag (CCD tag). Based on the successful results of the SEASTAR2000, the Thai government requested us to investigate migration behavior for the Mekong giant catfish as well as sea turtles. The Mekong giant catfish is endemic to the Mekong River but an endangered species now. Mekong giant catfish tracking project (MCTP) was started in 2002. The project was performed using coded ultrasonic transmitters in Mekong River.

1. Introduction

1.1. SEASTAR2000

The Southeast Asia sea turtle associative research (SEASTAR2000) started in 1999. The objectives of the SEASTAR2000 were as follows. 1. To clarify migratory paths of adult female green turtles in the Gulf of Thailand and the Andaman Sea, using satellite tracking system. 2. Monitoring of sand temperature using temperature recording data loggers in the nesting ground to estimate sex ratio of new-hatched individuals. 3. Genetic analyses of the local population structures of the sea turtle. 4. Correlation between fishing effort of trawling and the number of sea turtle by-catch. 5. Development of a scientific strategy for the conservation.

In the first step, the project emphasized on research of migratory paths both in the Gulf of Thailand and the Andaman Sea, Thailand using the Argos system. The sea turtle migratory paths were demonstrated in the Internet (http://bse.soc.i.kyoto-u.ac.jp/seastar2000/).

The results clarified migratory paths of adult female green turtles after their nesting; in the Gulf of Thailand they migrated to various sea areas sometimes even beyond Thai waters including the South China Sea, and in the Andaman Sea almost all the turtles migrated to the Andaman Islands within Indian territorial waters via different routes (Figure 1).

These findings, especially in the Andaman Sea raised a new problem whether there were other nesting beaches in the Andaman Islands or not. It was unfortunately that the Argos position data were not accurate in order to decide whether sea turtles habited only in the sea or landed to lay eggs occasionally.

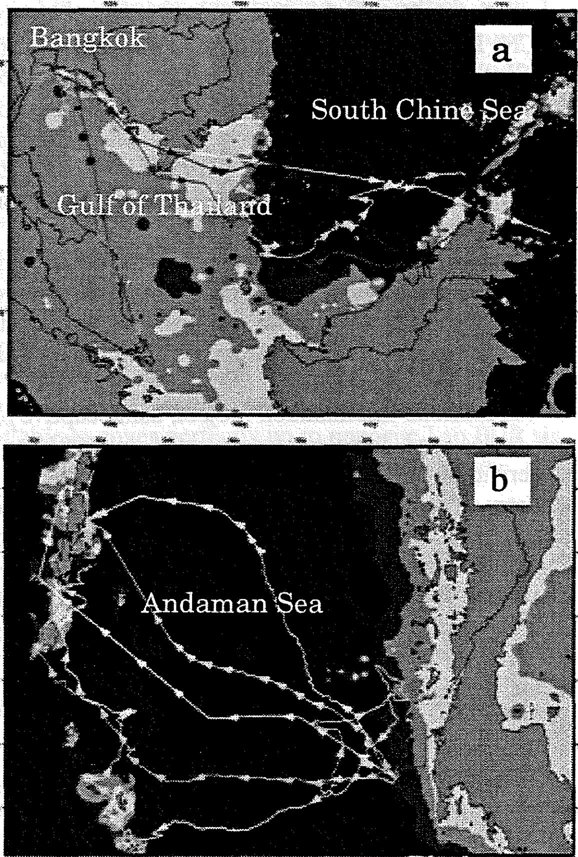

Figure 1. Results of the Argos tracking of adult female green turtles in the Gulf of Thailand (a) and the Andaman Sea (b).

Therefore new devices to analyze fine scale turtle behaviors were necessary to develop in the project.

They included a magnetic field sensor accelerometer tag (MR tag) and a GPS-Argos platform terminal transmitter (GPS-Argos PTT). The MR tag had three magneto-resistive effect sensors and accelerometers to record heading direction of a sea turtle and its movement intensity every 50 ms. The GPS-Argos PTT was a combination of the GPS positioning system and the Argos data transmission system. The position data were with 10 m accuracy. In addition, a visual data storage tag (CCD tag) that took pictures under water was developed.

1.2. MCTP

Mekong giant catfish or the *pla buk* in Thai, *Pangasianodon gigas* (Chevey, 1930), is endemic to the Mekong River. As its vernacular and English names indicate ("*buk*" means colossal or strong), *pla buk* is known for its huge size, attaining a length of 3m and a weight of more than 300kg in adults [1]. It is classified as 'endangered' species on the 2000 International Union for the Conservation of Nature (IUCN) Red List and also listed in the appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Therefore the fishing catfish is strictly regulated in Thailand. The only fishery cooperative permitted to catch the Mekong giant catfish in Thailand is located in Chiang Khong District in the northern part of Thailand. The fishermen in the cooperative use gill nets with a height of 3m and mesh width of 40cm. The fishing season starts from April and finishes by the end of the dry season, the end of May. Recently, the number of the catch decreased drastically.

An artificial insemination project, using captive *pla buk* males and females, was started in 1981 as a conservation purpose by the Department of Fisheries, Ministry of Agriculture and Cooperatives of the Thai government, and first success was achieved in 1983. A demonstration of the release of captured *pla buk* found in 1996 [1]. However, little is known of the ecology and feeding habitats of wild and released artificial *pla buk*. Especially, the migration behavior of the Mekong giant catfish is hidden in a veil of mystery.

The Mekong giant catfish tracking project (MCTP) was started to investigate migration behaviors for the catfish using ultrasonic biotelemetry by the request of the Department of Fisheries, Ministry of Agriculture and Cooperatives of the Thai government in 2001.

2. Materials and methods

2.1. SEASTAR2000

2.1.1. MR tag

The magnetic field sensor accelerometer has a magneto-resistive effect (MR) sensor and three accelerometers in it. The MR sensor detects 3D magnetic field to transform into 3D direction data. All the signals of the MR sensors and the accelerometers were converted by A/D converter to 12-bit digital data controlled by a microprocessor inside the tag. The dimension is 54 mm ø x 178 mm with ca. 1500g in the air and ca. 1000g in water. Two lithium dry cells (3B24TC x 2, 4000mAh) were equipped to provide ca. 65 mA for over 60 h.

We conducted the field test of the tags using adult sea turtles in the Sea Turtle Conservation Station of the Thai government. The Station was located at the Mannai Island in the Gulf of Thailand about 200 km eastward far from Bangkok.

Two magnetic field sensor accelerometers (MR tags) were attached to an adult hawksbill turtles *Eretmochelys imbrieata* (body weight: 65kg, curved carapace length: 83cm) and a green turtle *Chelonia mydas* (57kg and 80cm). The MR tags were attached using polyethylene pedestals which bottom were sharpened for the shape of sea turtle carapaces with epoxy resin. The MR tags were bound with some cable-ties (Figure 2).

The sampling rates of the MR tags were every 50 ms. The sample turtles were released in a seawater pond that was a rectangle ca. 200 m x 40 m with several meters depth at 12:40 on 13 March 2001 and recovered them at 13:20 on 15 March 2001.

The two MR tags recorded continuous data for 48 hours 50 minutes. The data included 3D magnetic field and 3D acceleration every 50 ms. 3D means surging (X), swaying (Y), and pitching (Z) directions.

An approximate direction („, degree) of the turtles was calculated using X and Y horizontal magnetic field data as follows;

„= 180 - arctan(Y/X) (X<0)
„= - arctan(Y/X) (X>0, Y<0)
„ = 360 – arctan(Y/X) (X>0, Y>0)
„ = 90 (X=0, Y<0)
„ = 270 (X=0, Y>0).

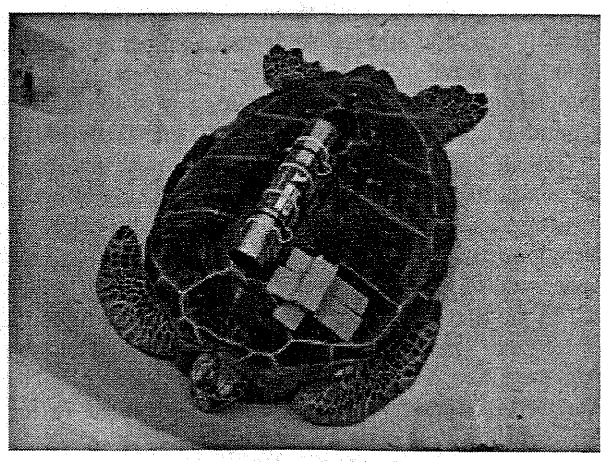

Figure 2. A green turtle attached with a MR tag (left) and a CCD tag (right).

2.1.2. GPS-Argos PTT

Several prototypes of the GPS-Argos PTTs were performed in the rearing pond also in the Mannai Island, Thailand. Based on the results, we improved them and performed an experiment in the open sea. The improved prototype was attached to a female green turtle with 103 cm CCL and 94 CWL. The turtle was released from a coast of Phangnga Province in the Andaman Sea on January 6, 2004 (Figure 3). The specifications of the GPS-Argos PTT were described in Table 1.

2.1.3. CCD tag

The visual data storage tag was installed with a complementary metal-oxide-silicon charge-coupled device (CMOS CCD) that took 100 black-and-white pictures with 28000 pixels and stored them in a 1 mega-byte flush memory. The dimension of the tag is 92 x 40 x 28 mm3, weighed ca. 200g in air and ca. 18g in water. It has an IrDA interface to transfer pictures to a personal computer. A prototype model has capacity to 100 m pressure and was timer-controlled to take pictures every one-hour. A lithium dry cell (CR2, 800mAh) provided enough currents for taking over 80 pictures.

2.2. MCTP

2.2.1. Study site and experimental fish

The study was conducted in the middle reaches of the Mekong River covered ca.110 km within Nakhon Phanom Province in 2002 (Figure 4).

We used ten Mekong giant catfish in 2002. These sample catfish were artificially inseminated in the Chiang Rai Inland Fisheries Research and Development Center and reared in the Nakhon Phanom Inland Fisheries Station.

2.2.2. Transmitters

We used ultrasonic coded transmitters V16-4H manufactured by Vemco Co., Ltd., Canada. They were 16 mm in diameter, 65mm long and weighed ca. 10g in water. The frequency of the transmitters was 69 kHz. The power of the acoustic signals was 153dB. The interval of the transmission was about 45 seconds. The battery lasted over two years. The transmitters transmit complex codes consisting of six pulses in a transmission. If the receiver perfectly receives all the six pulses of a transmitter, the receiver can identify and record the ID number of a transmitter. If the receiver can not identify the ID number, it records only the number of pulses. Two hundreds fifty six different fish were identified on the same frequency using this transmitter [2].

2.2.2. Experimental deployment

Before the actual experiment, we carried out experiments to determine effects of external and surgical transmitter attachment in the Kalasin Inland Fisheries Research and Development Center using dummy transmitters for a month. The result indicated that no external attachment transmitters remained after a month. Therefore all the transmitters were implanted surgically into the abdominal cavity of the catfish under the anesthesia following our previous method [3]. After the surgical treatment, the fish were kept in indoor tanks at least for 24hours to be observed the body condition before releasing experiments.

The sample catfish were released on 27th of June 2002 at a mouth of the Song Khram River that was one of the branches of the Mekong River (Figure 5).

2.2.3. Tracking system

We used VR1 receivers manufactured by Vemco Co., Ltd., Canada for tracking the catfish with the coded ultrasonic transmitters. The VR1 receiver was installed in the place at a middle water depth to record the attendance of the catfish with the transmitters. Dimension of the VR1 receiver was 60 mm in diameter and 205 mm in length and powered by the lithium battery lasted for 180 days. It had flush-memories inside to record the data. Information including the ID number and the time were recorded when the tagged fish passed in the expected detection range of the receiver. According to a test of the detection range, the receiver was able to detect the signals from the transmitter within about 300m in the main stream of the Mekong River. It means that the receivers were not able to cover perfectly up to opposite Lao PDR side in the flood season because the width of the river expands about 500–600 m.

2.2.4. Tracking periods and placement of stations

We installed five VR1 receivers, No.1-5, in the Mekong River (Figure 5). Two (Nos.3 and 4) of the five receivers were set up near the release station. One (No.5) receiver was set up at the Song Khram River that was a branch. Another (No.1) receiver was set up at the place about 60 km upstream of the release station, Bannakhae district in Nakhon Phanom Province. The other (No.2) was set up at the place about 50 km downstream of the release station in front of the River View Hotel in the down town of Nakhon Phanom. The data from five VR1 systems were downloaded on 18th of August 2002.

3. Results and discussion

3.1. SEASTAR2000

Figures 6 and 7 show a one-hour data of all the data logged in the MR tags attached to a hawksbill turtle (Figure 6) and a green turtle (Figure 7).

The X acceleration was expected to reflect swimming propulsion powered by turtle flippers. We calculated power spectrum density (PSD) of the X acceleration data of the hawksbill turtle (Figure 6c) and the green turtle (Figure 7c). Similar frequency of 0.31Hz was found in the both spectra. These frequencies were forced by water vibration. The peaks of 1.25Hz in Figure 6c and 0.86Hz in Figure 7c indicated the flipper beat frequencies.

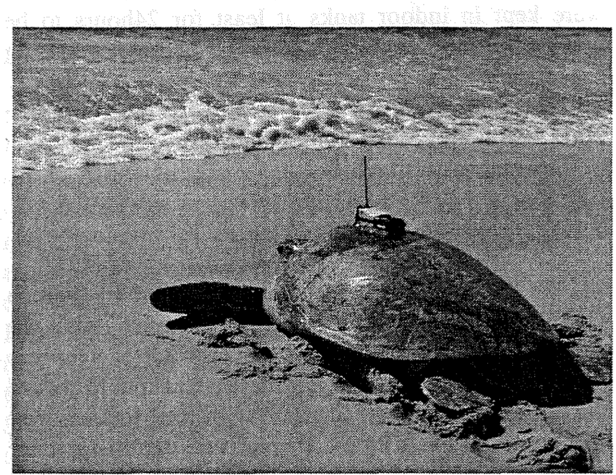

Figure 3. A green turtle attached with a GPS-Argos PTT.

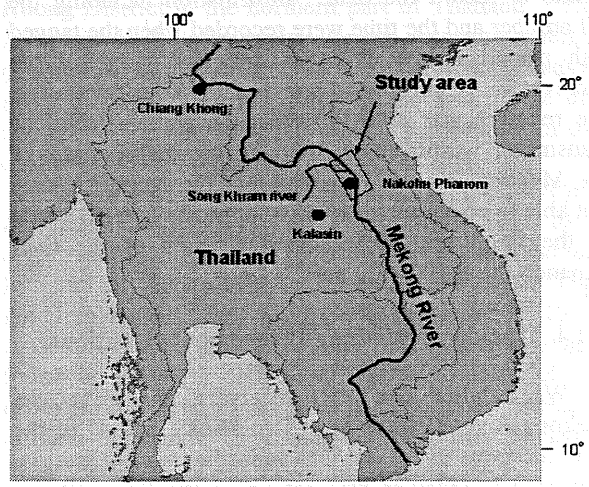

Figure 4. Location of the study area of the MCTP in 2002.

Table 1. Type T-2076 and T-2077 GPS-ARGOS PTT Specification

Transmitter type	T-2071
Transmitter Output power	1W
Operation days	10days
GPS interval	Programmable (max 4times/day)
Repetition period	45s
Antenna	Whip antenna
Data	GPS UTC Time GPS Location Surface time counter Battery voltage
Voltage range	6 Volts
Weight	600grams (T-2076) and 400grams (T-2077)
Dimensions	210 mm x 52 mm in diameter (T-2076) 190mm(w)x40mm(d)x38mm(h) (T-2077)

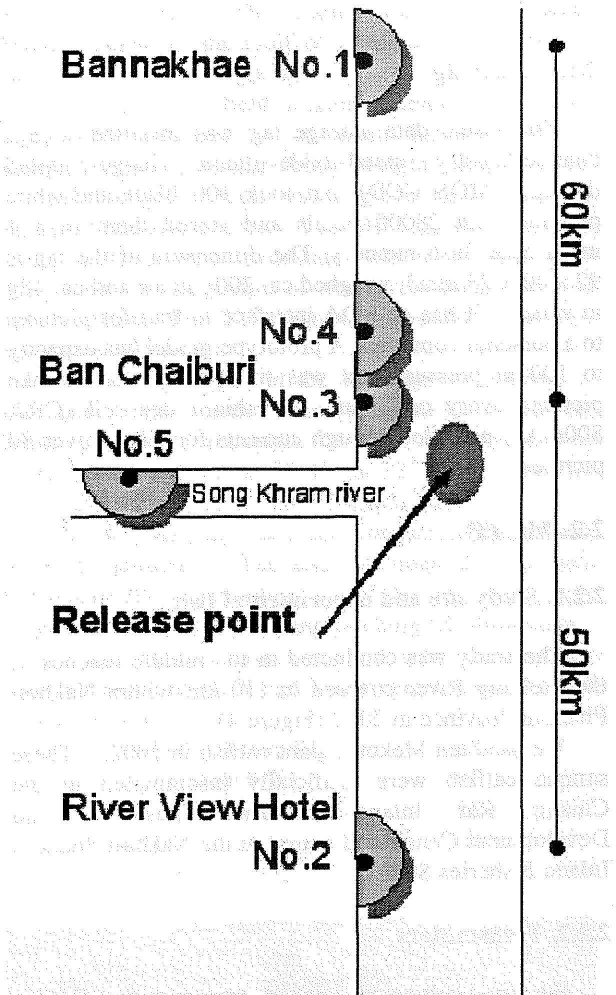

Figure 5. Setup plan of the VR1 receivers during 27th of June to 18th of August.

Figure 8 shows a direction of a hawksbill turtle from 13:39:40" to 13:46:36". The turtle was moving to the south with several changes of directions.

The MR tags were able to take data with high frequency. In the experiments, we took every 50 ms. The high frequency sampling produced an enormous amount of data. The data from the MR tags were too large to browse the whole data. We divided all the data into 44-piece one-hour period data. The one-hour period data including 6-channel data of 3D acceleration and 3D magnetic field amounted to ca. 7-megabyte. It will be necessary to develop a data-analyzing tool. Although we are only capable of computing the heading direction as shown in Figure 8, the figure is the first result which indicates the swimming direction of the free-range turtle under the water. The data will be very important for marine biology to investigate the feeding behavior under the water.

Recently, the acceleration data of free-range marine mammals has been investigated by accelerometers including penguins [4-6] and seals[7, 8]. Our intention is finally to combine the acceleration data 3D position. The appropriate procedures of integration of the acceleration data are under development now

Regarding the PSD of the X acceleration, we found interesting frequencies. In the PSD of both the hawksbill turtle and the green turtle, the same frequency 0.31Hz was found. We supposed the frequency is vibration of the seawater in the pond. The other frequencies 1.25Hz in the hawksbill turtle (Figure 6) and 0.86Hz in the green turtle (Figure 7) were also detected. Judging from videotape these frequencies indicate the turtle flipper frequencies.

We employed 22 Argos PTTs to track green turtles both in Thailand and Malaysia in 2000 and 2001. The total Argos satellite transmissions from the PTTs amounted to 7463 in 2000 and 5071 in 2001 as of 21 November. The location classes (LC) obtained from the PTTs was evaluated. The results were not satisfactory since almost half of the Argos data determined no location (59% in 2000 and 42% in 2001). Table 2 shows the same tendency that nearly half data of the total Argos data indicated LC Z which had invalid location. In that case, the GPS data were transmitted within 10m accuracy. In contrast, the result of the GPS-Argos PTT was very satisfied. We found that the PTT could send position data by GPS even in the case of LC Z (Figure 9).

Two CCD tags also worked well as we expected throughout the experiment. The CCD tag was equipped with a CdS light sensor switch not to put up the shutters in the night since the tag had no flush light. Figure 10 shows one of scenes of the CCD tag on the green turtle. Besides the scene was not clear, the small part of the head area was identified. When the turtle looked up, her own head came within the range of the CCD tag. The other small object was also identified in the scene. We supposed this object was a small fish judging from some similar pictures of small fishes taken by the underwater digital camera taking every 7 minutes in the fixed point continuously.

Generally speaking, visual data are very exciting and useful for all the researchers. Davis et al. [8] reported hunting behavior of Weddell seals beneath the Antarctic fast ice using a small video system attached on their backs. They concluded that the vision is important for hunting in Weddell seals. We agree in this conclusion but we had no small and smart devices to be attached on the smaller mammals. Our prototype is relatively small and light enough to be attached on the sea turtles; the weight of the CCD tag is only 0.04% of the body weight of the smallest sample sea turtle. There are several points to improve; one is to change a black-and-white CCD into a color CCD; a second is to change a fixed shutter period into a programmable period; and a third is to install a flash light. We are now improving all of them step-by-step.

3.2. MCTP

All the VR1 receivers worked well and detected signals from the coded ultrasonic transmitters in the sample catfish. The No.3 at the release station recorded all the IDs 1-10. It indicated that all the transmitters were well working inside the catfish. Table 2 shows number of detection by all the VR1 receivers downloaded on 18th of August 2002.

ID 1 went out of the range of No.3 just after the release at 17.00 hours on 27th of June 2002. Then it came back around the release station and stayed between No.3 and 4 during 27th of June to 1st of July 2002. In the evening on 1st of July, it went out of the range of No.3 and 4. It appeared again in 60km upward No.1 station and stayed for 01.02 hours around No.1 station. ID 2 was released at 12.07 hours and stayed for 10.34 hours around the release station then disappeared. ID 3 was released at 16.58 hours and stayed there for two hours. It dropped also in a branch, No. 5, very shortly. It disappeared during 28th of June to 3 July then came back to No.4 and went up to the 60km on 6th of June. ID 4 went out of the release station just after the release and never came back. ID 5 was released at 12.11 hours and stayed around the release station for five days. It stayed on balance near 500m upward, No.4 on 28th of June because more number of detection was recorded in the No.4 than in No.3. ID 6 was released at 17.01 hours and went into a branch around No.5 on 28th of June and stayed there for three days. Then it moved to the main stream on 1st of July 2002. After that, it swam up to the 60km upward to the station and passed the station. ID 7 was released at 17.03 hours and stayed for two hours. Then it moved out of the release station and appeared around the mouth of the branch on 3rd of July 2002. ID 8 was released at 09.06 hours and stayed for 05.16 hours and disappeared. After six days, it appeared around 500m upward from the release station. ID 9 was released at 08.58 hours and went out of the release station. It appeared again at 50km downward on 4th of July and passed down. ID 10 was released at 16.59 hours and disappeared at once and never came back around all the stations.

It was a successful result that all the VR1 receivers recorded the ID number of the sample Mekong giant catfish in the wide area covered ca. 110km long. However, the detection range of the VR1 receivers was limited within a ca. 300m radius so that it was impossible to detect the signals when the catfish moved to the opposite area, i.e. Lao PDR side. Disappearance of IDs 2, 4 and 10 just after the release indicated that they moved out from the detection range. The receivers should be installed also in Lao PDR side in the future to track the catfish perfectly.

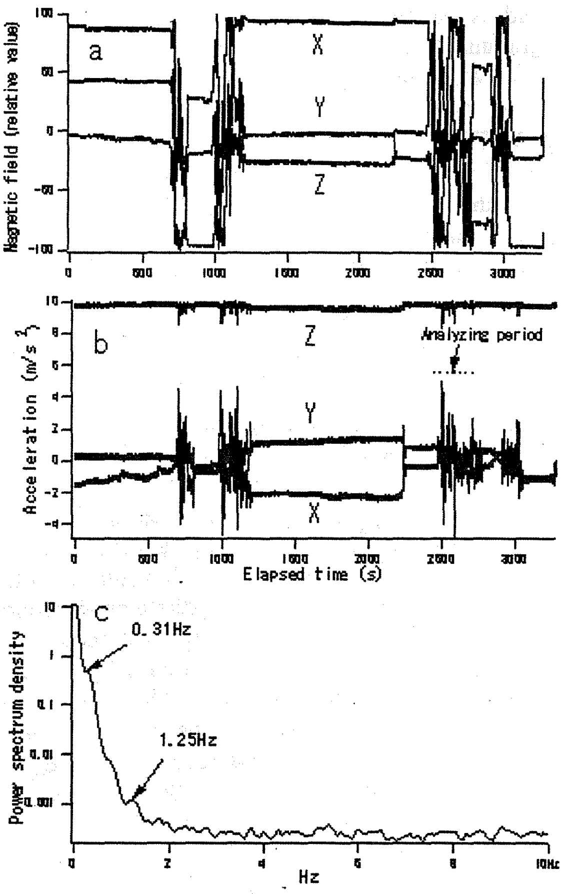

Figure 6. The data from a hawksbill turtle. (a, b) indicates one-hour data of 3D acceleration and magnetic field data. (c) is a power spectrum density of the X acceleration in the analyzing period indicating in b.

The V16 coded transmitter sent ultrasonic signals every 45 seconds on average. The signal interval varied randomly ranging from 20 to 90 seconds in order to avoid crosstalk each other. Therefore, the number of the detection ought to be 1920 times a day on average. From this point of view, ID 5 on 29th of June (1367 times) and on 30th of June (1555 times) at VR1 No.3, and ID 6 on 28th –30th of June (1670, 2110 and 1753 times) at No.4 indicated that they inhabited all the time within a 300m radius from the VR 1 receiver, respectively. Moreover, it is clear that ID 6 came into the Song Khram River on 28th of June and stayed there until 30th of June (Table 2).

The data of the VR 1 receiver shows us the time of fish attendance in a 300m radius area. It is just like an attendance book of the fish. We can assume fish's moving behavior using two attendance books. ID 1 went out from No.4 at 20.58 hours on 1st of July and attended No.1 at 11.00 hours on 4th of July. It took 38 hours and two minutes from No. 4 to No. 1. In the same way, IDs 3, 6 and 8 took 52 hours and 8 minutes, 55 hours and 49 minutes and 44 hours and 38 minutes, respectively. They swam up ca. 60km from No.4 to No.1 for 49 hours and 39 minutes on average. Supposing that the catfish swam 12 hours a day, the average moving speed (V) was 178 cm/s considering the velocity of river current, ca. 2km/h, that was measured by a GPS on the boat. An average body length (l) was 87±20cm so that the 178cm/s was converted into two l/s. This is appropriate value according to the preceding studies [9, 10].

Only ID 9 appeared at No. 2, 50km downward from the release station on 4th of July 2002. We should be careful about downward moving because the dead fish also was drifting in the current. If the fish was dead, it flowed across a 600m diameter of the No.2 for 18 minutes supposing the velocity of the river was 2km/h. Therefore, in this case the catfish ID 9, whose signals were recorded during 09.58-10.53hours on 4th July in No.2, seemed not to be dead (Table 2).

The second downloading on 23rd of November 2002 gave us no ID number at all. However fractions of the ultrasonic coded signals were recorded in all the VR1 receivers shown in Table 3. Especially, No. 4 located 15km far from the release station stored 7089 pulses for 97 days, 18th of August 2002 to 23rd of November 2002. It indicated that some sample catfish inhabited near the No. 4 but a little bit far from the detection range between the VR1s or inhabited opposite areas, i.e. Lao PDR side in the Mekong River.

We started two new tracking experiments in 2003 both in the Mekong River and in a reservoir; the Mae-puem Reservoir located in Phayao Province has an area of around 816km^2 completed in 1982. The former covers over 1200km from Chiang Khong to Khong Chiam. The other aims to clarify vertical and horizontal movement of the catfish using fourteen VR2 receivers and V16P transmitters with pressure sensors.

4. Acknowledgements

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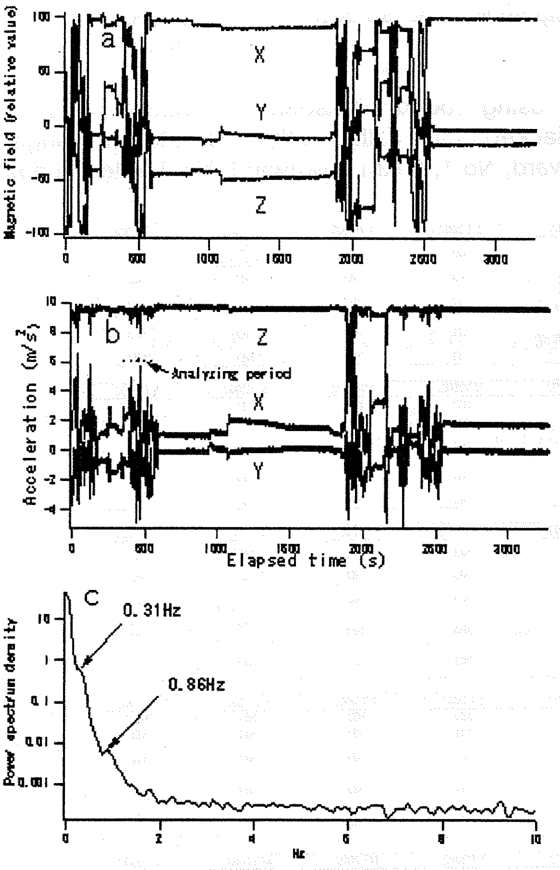

Figure 7. The data from a green turtle. (a, b) indicates one-hour data of 3D acceleration and magnetic field data. (c) is a power spectrum density of the X acceleration in the analyzing period indicating in b.

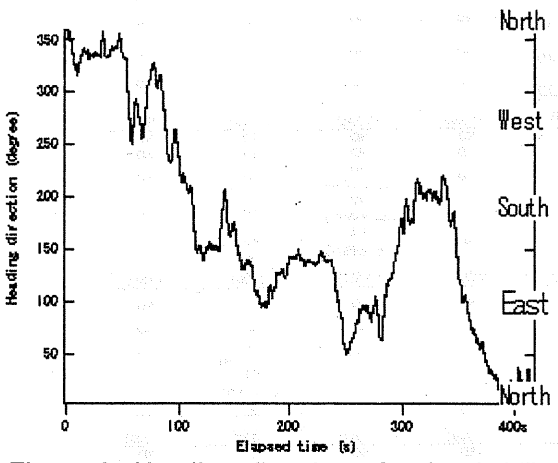

Figure 8. Heading direction of a hawksbill turtle computed by X and Y magnetic field data for a term of 412 seconds.

[4] Yoda, K., Sato, K., Niizuma, Y., Kurita, M., Bost, C.A., Le Maho, Y. and Naito, Y. (1999). Precise monitoring of porpoising behaviour of Adélie penguins determined using acceleration data loggers. *J.Exp.Biol.* **202**, 3121-3126.

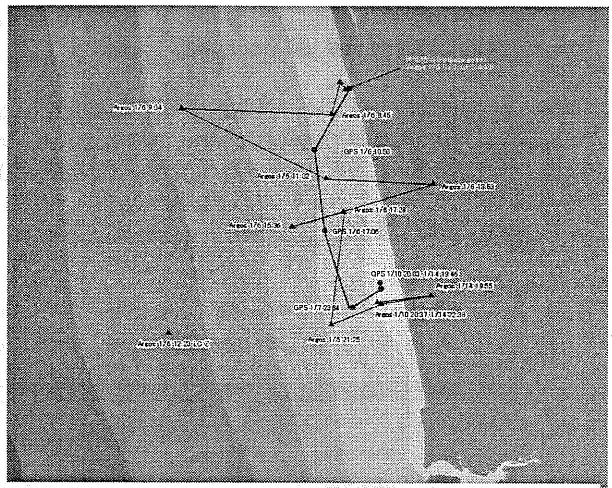

Figure 9. The results of a GPS-Argos PTT. A red points show the data of the GPS and black ones show the Argos position data.

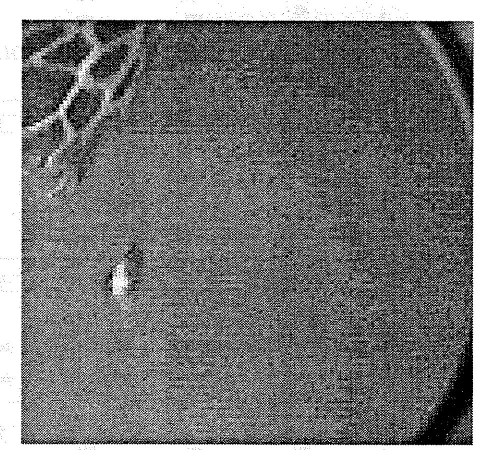

Figure 10. One scene of the CCD tag on the green turtle. The small part of the head and a small fish were identified in this picture. Objects at the upper right and the lower right were the window frame of the CCD tag.

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Table 2. Results of the Mekong giant catfish tracking using coded ultrasonic transmitters and VR1 receivers. Number of detection and attendance time (in blacket) of the catfish within the detection range of each VR1 receiver. VR1 receivers were located 60km upward, No.1, 50km downward, No.2, release point, No.3, 500m upward, No.4 and a branch, No.5.

ID 1 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	82 (11.00-12.02)	ND
2 •	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	6 (17.00-17.10)	836 (05.31-23.59)	726 (00.00-23.54)	781 (00.15-23.58)	543 (00.01-19.16)	ND	ND	ND	ND
4	ND	89 (06.09-23.64)	414 (00.01-23.59)	514 (00.26-23.58)	227 (00.01-20.58)	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND	ND	ND	ND

ID 2 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	925 (12.07-22.41)	ND	ND	ND	ND	ND	ND	ND	ND
4	43 (14.44-20.16)	ND	ND	ND	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND	ND	ND	ND

ID 3 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	45 (16.58-18.57)	ND	ND	ND	ND	ND	ND	5 (04.18-04.41)	ND
4	5 (17.04-18.48)	ND	ND	ND	ND	ND	ND	249 (04.14-06.55)	ND
5	4 (16.59-17.02)	ND	ND	ND	ND	ND	ND	ND	ND

ID 4 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	7 (17.02-17.24)	ND	ND	ND	ND	ND	ND	ND	ND
4	4 (17.09-17.23)	ND	ND	ND	ND	ND	ND	ND	ND
5	1 (17.04)	ND	ND	ND	ND	ND	ND	ND	ND

ID 5 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	355 (12.11-23.55)	350 (00.00-23.59)	1367 (00.00-23.58)	1555 (00.00-23.59)	809 (00.00-12.09)	ND	ND	ND	ND
4	51 (13.45-23.57)	604 (00.00-23.59)	417 (00.01-23.47)	617 (00.01-23.43)	349 (00.33-14.29)	ND	ND	ND	ND
5	3(00.12)	ND	ND	ND	ND	ND	ND	ND	ND

ID 6 VR1 No.	27/6/2002	28/6/2003	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2003	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	67(00.42)		
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	28 (17.01-18.54)	424 (02.44-10.05)	11 (04.35-04.43)	257 (10.07-14.25)	310 (00.30-07.55)	ND	ND	ND	ND
4	ND	12 (03.10-06.25)	ND	118 (10.28-13.53)	447 (00.52-09.33)	ND	ND	ND	ND
5	1 (17.04)	1670 (07.46-23.59)	2110 (00.00-23.59)	1753 (00.00-23.58)	64 (00.00-00.35)	ND	ND	ND	ND

ID 7 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	82 (17.03-19.10)	ND	ND	ND	ND	ND	266 (01.42-07.30)	ND	ND
4	22 (17.07-18.27)	ND	ND	ND	ND	ND	182 (02.29-09.03)	ND	ND
5	ND	ND	ND	ND	ND	ND	372 (04.06-06.52)	ND	ND

ID 8 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	439 (09.06-14.25)	ND	ND	ND	ND	ND	ND	60 (12.02-12.58)	ND
4	7 (10.03-14.24)	ND	ND	ND	ND	ND	ND	233 (12.28-14.50)	ND
5	ND	ND	ND	ND	ND	ND	ND	ND	ND

ID 9 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2002	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	88 (09.58-10.53)	ND
3	233 (08.58-12.02)	ND	ND	ND	ND	ND	ND	ND	ND
4	51 (11.19-12.03)	ND	ND	ND	ND	ND	ND	ND	ND
5	1 (11.38)	ND	ND	ND	ND	ND	ND	ND	ND

ID 10 VR1 No.	27/6/2002	28/6/2002	29/6/2002	30/6/2002	1/7/2002	2/7/2002	3/7/2003	4/7/2002	5/7/2002
1	ND	ND	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND	ND	ND
3	3 (16.59-17.00)	ND	ND	ND	ND	ND	ND	ND	ND
4	5 (17.00-17.07)	ND	ND	ND	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND	ND	ND	ND

Development of a GPS-Argos PTT for marine animal tracking

(Argos animal tracking symposium ポスター発表)

by

Nobuaki Arai, Kazuhiko Ono and Koichi Mizuno

上会情報学専攻
Graduate School of Informatics, Kyoto University

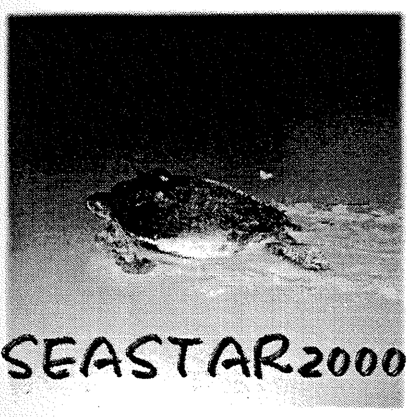
TOYOCOM

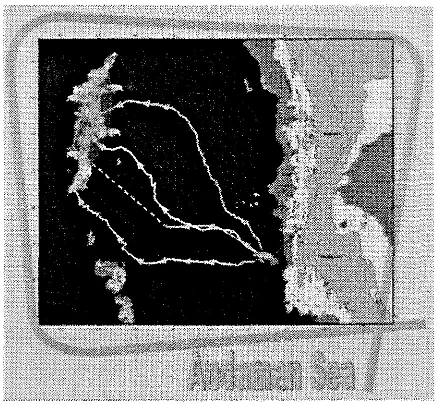
Development of a GPS-Argos PTT for marine animal tracking

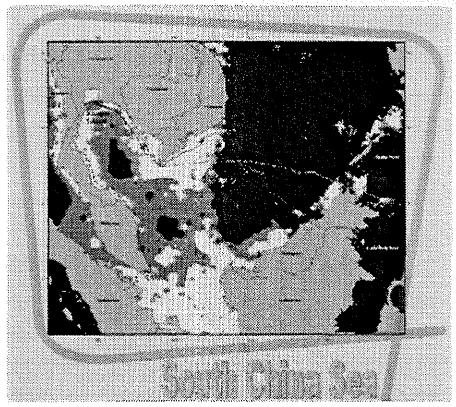
Nobuaki Arai[1] , Kazuhiko Ono[2] and Koichi Mizuno[2]

[1] Graduate School of Informatics, Kyoto University [2]Toyo communication equipment Co., Ltd.

The Southeast Asia sea turtle associative research, SEASTAR2000 (Fig.1) was started in 1999 as the Japan-Thai cooperative research by the fund of Kyoto University. The project was mainly focused on the research of migration behavior of adult female green turtles during post nesting periods around the Gulf of Thailand and the Andaman Sea using Argos PTTs. The results are summarized in Figs.2 and 3. We found that the post nesting turtles migrated far away from Thai waters. Especially in the Andaman Sea, almost the green turtles migrated to the Indian-owned Andaman Islands. We supposed that the turtles fed in the coastal areas around the Andaman Islands but we had no data about these areas. In addition, the turtles might also lay eggs on the beach around the Andaman Islands. If the position of the turtles is determined accurately, we can estimate whether the turtles landed to lay eggs or not. It is unfortunate that the conventional Argos PTT cannot realize the accuracy.







We employed 22 Argos PTTs to track green turtles both in Thailand and Malaysia in 2000 and 2001. The total Argos satellite transmissions from the PTTs amounted to 7463 in 2000 and 5071 in 2001 as of 21 November. The location class (LC) obtained from the PTTs was evaluated. The results were not satisfactory since almost half of the transmissions were only one uplink and determined no location (59% in 2000 and 42% in 2001). (Fig.4)

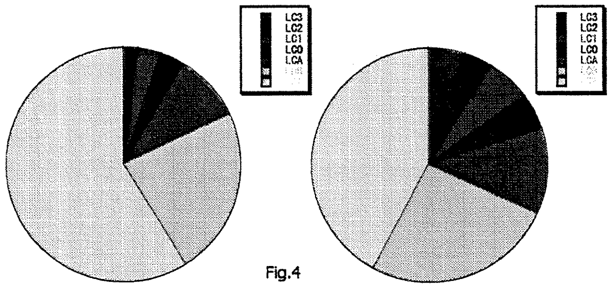


Fig.4

Since principal of the GPS is based on time not on the Doppler effect as Argos system, it does not need multi uplinks to the satellite. Once location data are obtained by the GPS, the GPS-Argos PTT stores the location data onto inside memories. We developed several prototypes of the GPS-Argos PTT (Figs.5-7) installed with a brand-new miniaturized transmitter T-2071 manufactured by TOYOCOM.

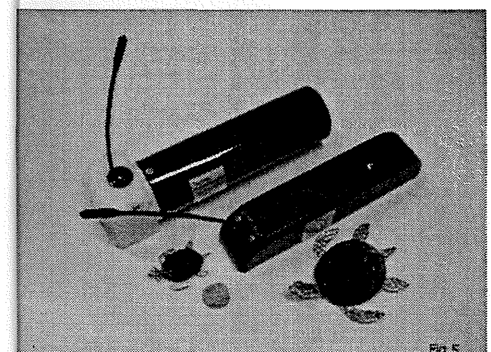


Fig.5

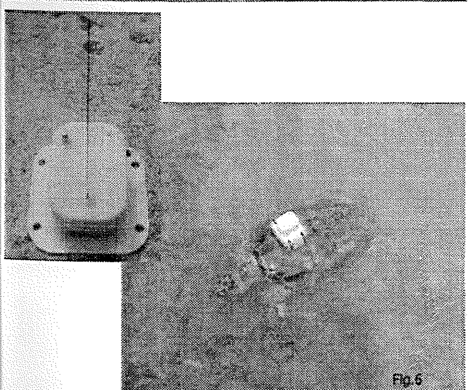


Fig.6

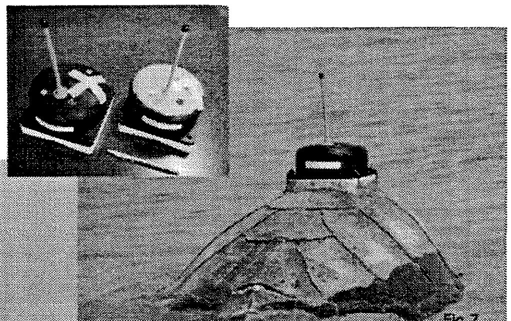
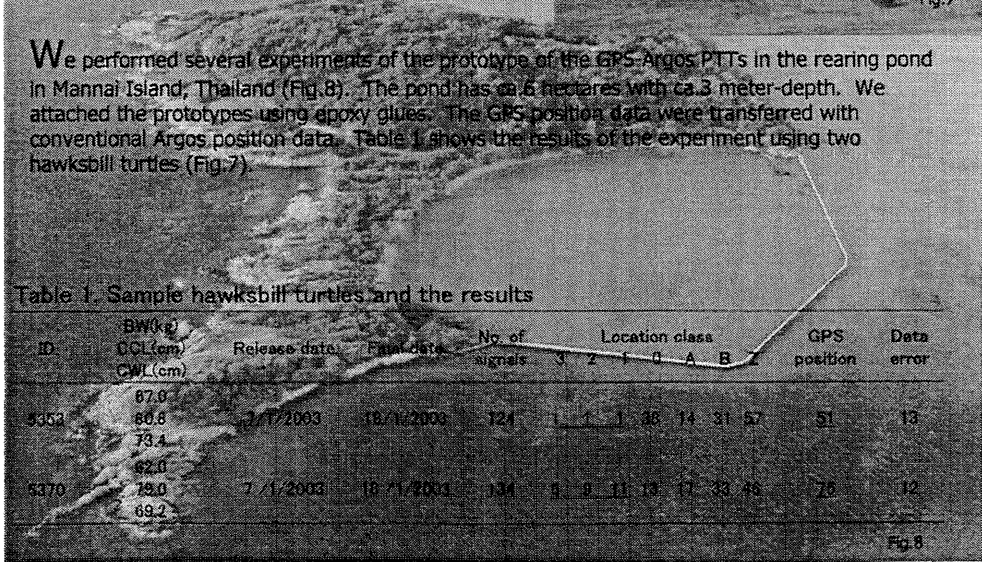


Fig.7



We performed several experiments of the prototype of the GPS-Argos PTTs in the rearing pond in Mannai Island, Thailand (Fig.8). The pond has ca.6 hectares with ca.3 meter-depth. We attached the prototypes using epoxy glues. The GPS position data were transferred with conventional Argos position data. Table 1 shows the results of the experiment using two hawksbill turtles (Fig.7).

Table 1. Sample hawksbill turtles and the results

ID	BW(kg) CCL(cm) CWL(cm)	Release date	Final date	No. of signals	Location class 3	2	1	0	A	B	Z	GPS position	Data error
5353	67.0 80.8 73.4	2/1/2003	18/1/2003	124	1	1	1	38	14	31	57	51	13
5370	62.0 79.0 69.2	7/1/2003	18/1/2003	134	5	9	11	13	17	33	46	75	12

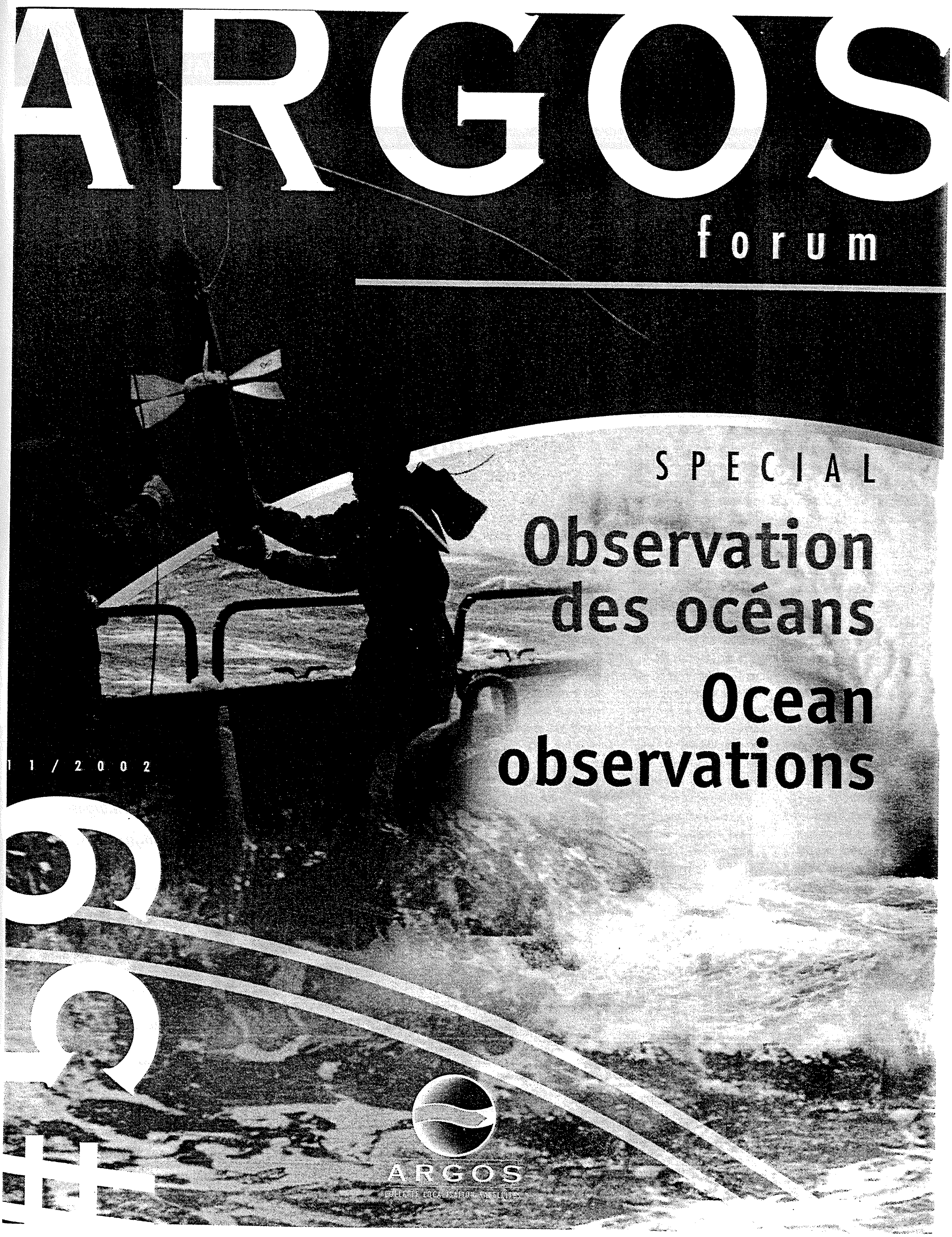
Fig.8

Development of a GPS-Argos PTT for marine animal tracking

(*ARGOS forum*, **59**, 19, 2002))

by

Nobuaki Arai and Kazuhiko Ono


ARGOS
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Observation des océans
Ocean observations
11/2002
ARGOS

Nobuaki Arai *(Graduate School of Informatics, Kyoto University)* & **Kazuhiko Ono** *(Toyo communication equipment Co., Ltd.)*

Mise au point d'un émetteur
GPS-Argos PTT
pour le suivi des animaux marins

Nous avons utilisé 22 émetteurs pour suivre les tortues vertes en Thaïlande et en Malaisie en 2000 et 2001. Les émetteurs PTT ont transmis au total 773 messages vers les satellites Argos en 2000 et 4813 messages en 2001. La classe de localisation (LC) obtenue des émetteurs PTT a été évaluée mais les résultats n'étaient pas satisfaisants car près de la moitié des transmissions ne correspondait qu'à une seule liaison montante et ne permettaient pas de déterminer la localisation.
Dans ce contexte, nous avons décidé de mettre au point un émetteur résultant d'une combinaison entre des systèmes GPS-Argos et PTT. Le GPS est également un système de navigation par satellite composé d'un réseau de 24 satellites placés en orbite. Le principe du GPS étant basé sur des informations temporelles et non sur l'effet Doppler à l'instar du système Argos, il ne nécessite pas de liaisons montantes multiples vers le satellite. Une fois que le GPS a transmis les données de localisation, l'émetteur GPS-Argos PTT enregistre les données sur des mémoires internes. L'émetteur PTT peut alors transmettre des informations sur la localisation ainsi que les données des capteurs par les satellites Argos. Même si l'émetteur PTT ne transmet qu'un seul message, les données peuvent être communiquées aux utilisateurs. Nous sommes à présent en train de mettre au point deux prototypes d'émetteurs GPS-Argos PTT équipés d'un émetteur miniaturisé tout nouveau T-2071 fabriqué par la société TOYOCOM.
L'un d'entre eux (T-2077) est rempli de résine époxy d'environ 190 x 40 x 38 mm^3 et l'autre (T-2076) est un émetteur réutilisable fabriqué dans un cylindre en fibre de glace d'environ 210 mm x 52 mm de diamètre qui seront testés plusieurs fois. Le premier essai pratique s'effectuera en Thaïlande. Nous espérons obtenir des données précises sur la localisation des tortues de mer au moins toutes les 6 heures à 10 m près. ■

Development of a
GPS-Argos PTT
for marine animal tracking

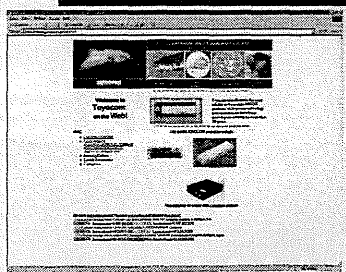
We employed 22 Argos PTTs to track green turtles in both Thailand and Malaysia in 2000 and 2001. The total Argos satellite transmissions from the PTTs amounted to 773 in 2000 and 4813 in 2001.
The location class (LC) obtained from the PTTs was evaluated. The results were not satisfactory since almost half of the transmissions had only one uplink and a location can not be determined.
With these results, we decided to develop a combined GPS-Argos PTT. Once location data are obtained by the GPS, the GPS-Argos PTT stores the location data onto internal memory cards. The PTT can then send information including location and sensor data via Argos satellites. Even when only one message from the PTT is received, the data can still be sent to users. We are now developing two prototypes of the GPS-Argos PTT installed with a brand new miniaturized transmitter T-2071 manufactured by TOYOCOM. One is a potting type (T-2077) filled with epoxy resin with ca. 190 x 40 x 38 mm3 and the other (T-2076) is a reusable type built in a glass-fiber cylinder with ca. 210 mm x 52 mm in diameter, both are to be tested several times. We will perform the first field trial in Thailand. We expect to obtain accurate sea turtle locations at least every 6 hours within 10 m. ■

Type T-2076 & T-2077 GPS-ARGOS PTT

Type de l'émetteur	Transmitter type	T-2071	
Puissance de sortie de l'émetteur	Transmitter Output power	1W	
Temps de fonctionnement	Operation days	10 jours (flottement continu)	10 days (continuation floating)
Intervalle GPS	GPS interval	Max 4 fois/jour (6h/jour)	Max 4 times/day (6h/day)
Période de répétition	Repetition period	45 s	
Antenne	Antenna	Antenne-fouet	Whip antenna
Données	Data	Heure TUC GPS Localisation GPS Compteur de temps à la surface Tension de la pile	GPS UTC Time GPS Location Surface time counter Battery voltage
Plage de tension	Voltage range	6 Volts	
Poids	Weight	600 g (T-2076) & 400 g (T-2077)	
Dimensions	Dimensions	Ø 210 mm x 52 mm (T-2076)	
		190 mm (l w) x 40 mm (p d) x 38 mm (h h) (T-2077)	

>>> www.argos-toyocom.jp/index.html

Toyocom, constructeur de balises, a récemment ouvert un site web dédié à leurs développements et leurs projets Argos.



>>> www.argos-toyocom.jp/index.html

Toyocom, transmitter manufacturer, recently opened a website which features their Argos transmitter developpments and projects.